An assessment of the conservation status of *Restrepia* (Orchidaceae) reveals the threatened status of the genus

For Peer Review Only

Abstract

***Background*:** The genus *Restrepia* occurs throughout Central and South America in areas of montane forest heavily affected by deforestation and is potentially facing a high level of threat as a consequence.

Aims: The current study was designed to test the feasibility of using available online resources to establish the threats facing these orchids and their conservation status for later inclusion in the IUCN online data base.

Methods: Online resources were searched for primary data on the distribution of species of *Restrepia*. The Geospatial Conservation Assessment Tool (GeoCAT) was used to produce semi-automated IUCN Red List assessments. Locations of populations were examined in Google Earth to establish habitat loss. A comparison of the data produced a Red List assessment for each species.

Results: The observed losses of *Restrepia* habitat were: Venezuela 45% of recorded locations for 15 species, Colombia 28% for 30 species, Ecuador 36% for 18 species, Peru 41% for eight species, Costa Rica 81% and Panama 32% for three species. This habitat loss coincided with the route of the Pan American Highway in these countries.

Conclusions: It was possible to establish the Red List Status of *Restrepia* species even with minimal data. The degree of threat facing these and other epiphytic orchid genera in these habitats was shown to be considerable.

Key words: Central and South America; deforestation; endangered categories; GeoCAT; Red List; *Restrepia.*

For Peer Review Only

Introduction

Restrepia is a small orchid genus comprising 61 species (WCSP 2018*)* belonging to the Pleurothallidinae, the largest sub-tribe in the Orchidaceae. These species are found throughout Central America and in Venezuela, Colombia, Ecuador, Peru and Bolivia in South America, growing at elevations between 1000 – 3000 m a.s.l. in areas of montane rain forest. These forests were identified as deforestation 'hotspots' by Mittermeier et al. (1999). Habitat loss and orchid population decline in these regions has been ongoing (Mittermeier et al. 1999; Myers et al. 2000; Brooks et al. 2002; Bubb et al. 2004; Millner 2013) and from this, it is reasonable to assume that all epiphytic species, including *Restrepia*, face significant threats to their populations. However, to date, the majority of *Restrepia* species have not been evaluated against Red List Criteria to determine their degree of threat. Therefore, this study was designed to use information and data currently available online to determine the degree of threat facing this genus and to establish their Red List status, for later inclusion in the IUCN online data base.

Figure 1 near here

The only comprehensive review of the genus is the monograph by Luer (1996a), which does not include the most recently described species. The type species for the genus, *Restrepia antennifera* (Humboldt et al. 1816) was described in 1801 (Figure 1). Together with other early discoveries, such as *R. contorta, R. brachypus* and *R. guttulata* it is widely distributed geographically and exhibits a high degree of within-species variation. The majority of *Restrepia* species have been identified after 1980 and many of which have only been identified from one or two locations (Luer 1996a). While these may persist in other localities in the wild, they have a narrower geographical distribution compared to those discovered earlier. Species discovered since 1996

For Peer Review Only

include *R. piperitosa* (Luer 1998), *R. portillae* (Luer 2002) and *R. fritillina* (Luer 2007). Most recently, five species have been described in Guatemala: *R. mayana* Archila, *R. archilae* and *R. cobanensis*, (Chiron and Szlachetko 2013a, b, c), *R. nicolasii* Archila (Szlachetko and Chiron 2017) and *R. valverdii* Archila (Rodriguez and Veliz 2015). None of these most recently identified species are widespread and to date, have not been found elsewhere.

In Central America and Mexico, only two widespread species are known, having their centres of distribution in Costa Rica and Panama. Both were described prior to 1930 - *R. muscifera* (Lindley 1859) and *R. trichoglossa* (Lehman 1901). *R. trichoglossa* is also found throughout Venezuela, Colombia, Ecuador and Peru (thus making it the most widespread and common *Restrepia* species) and *R. muscifera* is found in Colombia. One other species, *R. aberrans,* is native to Central America. This was first identified in Panama in 1996 (Luer 1996b), and has only been found in one other location since (Tropicos 2018).

The remaining species have their centre of distribution in the montane forests of the Andes of Colombia and Ecuador (Luer 1996a). Many have only been recorded once or twice in the wild and may be considered to occur as narrow endemics. This includes *R. howei,* which has no recorded locations, and nothing is known of its distribution in the wild (Luer 2005).

These tropical montane forests occur typically between 2000 – 3500 m a.s.l. (Philips 1997) where local climatic conditions often cause cloud and mist to be in contact with the vegetation (Whitmore 2001; Corlett and Primack 2011). These forests contain a disproportionately large number of endemic and threatened species, especially epiphytes (Whitmore 2001; Corlett and Primack 2011). For many of these species, their numbers and distribution have yet to be recorded (Armenteras et al. 2003). Threatened both by human pressures and climate change impacting on

For Peer Review Only

temperature, rainfall and cloud formation (Benzing 1990; Bubb et al. 2004; Bruijnzeel 2004), they are also threatened by changes in land use; such as the felling of trees for timber, farming or mining, all of which leading to deforestation. In the Eastern Colombian Andes, for example, the most altered and fragmented ecosystems correspond to montane and sub-montane forests (Armenteras et al. 2003). How such habitat fragmentation and change is affecting *Restrepia* species in these regions is unknown.

In the 1980s, it was realised that there was an urgent need to identify montane forest areas with high concentrations of endemic species facing significant environmental threat(s). So, the 'hotspots' analysis of tropical rain forests (Myers 1988) was extended (Myers 1990) to include them. By definition, a 'hotspot' contains at least 1,500 species of vascular plants as endemics and has lost at least 70% of its original habitat (Myers 1988). These forest 'hotspots' contain 45% of known plant biodiversity (Myers et al. 2000). In such biodiversity 'hotspots' of the Ecuadorian Andes, epiphytes constitute 30% of the vascular plant species (Kuper et al. 2004) and orchid 'hotspots' coincide with these (Cribb and Govaerts 2005). The centres of diversity for *Restrepia* species also coincide with these centres of orchid and epiphyte diversity.

Figure 2 near here

Figure 2 (Maps A, B and C) illustrates that montane forest distribution, Andean deforestation 'hotspots', and the geographical distribution of *Restrepia* coincide; thus, highlighting the threatened nature of *Restrepia* habitats throughout South America. It seems reasonable to assume that many individual *Restrepia* species have been exposed to the threat of deforestation and that their populations have declined consequently.

For Peer Review Only

In recent years, the importance of *ex situ* conservation of plant species has become widely accepted (Maunder et al. 1997; Fay and Krauss 2003; BGCI 2012; Mounce et al. 2017) and it is essential to be able to carry out conservation assessments from which to formulate conservation strategies. Online resources for plant conservation all share the common aim of making data freely available for conservation research, these include Tropicos (2018), the Herbarium Collections, Royal Botanic Gardens Kew (2018) and the Global Biodiversity Information Facility (GBIF 2018). Accurate and detailed studies of present and past species distribution patterns may now be undertaken which were not previously possible.

The International Union for Conservation of Nature (IUCN) Species Programme has been working with the IUCN Species Survival Commission (SSC), since 1975 to assess the conservation status of species worldwide in order to highlight taxa threatened with extinction, and promote their conservation (IUCN 2018). The IUCN Red List of Threatened Species (hereafter the Red List) (IUCN 2018) has been published solely online since 2001. It provides taxonomic, conservation status and distribution data on plants and animals that have been globally evaluated using the IUCN Red List Categories and Criteria (IUCN 2012). This system was designed to determine the relative risk of extinction of species at a global scale.

Currently, only *Restrepia trichoglossa* has been assessed and published on the Red List (IUCN 2018). The most recently published National Red Lists for Ecuador (Léon-Yánez et al. 2011) and Colombia (Calderon-Sáenz 2007) both list *Restrepia* species. In the Colombian National Red List, endemic species such as *R. cuprea, R. pandurata* and *R. falkenbergii* are listed as Critically Endangered (CR). Such endemic species presently categorised as Nationally Endangered or more threatened categories, if assessed at the global level, could also be listed as Endangered, but currently are not.

For Peer Review Only

Until 2010 there were few effective tools that took primary biodiversity data, such as those provided through herbarium records, and used them to make analyses of the geographic range of a species (Bachman et al. 2011). The Geospatial Conservation Assessment Tool (GeoCAT) online facility was developed to fill this gap and harnesses primary biodiversity data for semi-automated IUCN Red List assessment and analysis (Bachman et al. 2011). This tool has been made freely available through the internet to give conservationists easy access to a fast, quantifiable and reliable species conservation assessment tool (Bachman et al. 2011). At present, this tool can only produce a preliminary assessment based on extent of occurrence (EOO) and area of occupancy (AOO). It does not report on the sub-criteria that are required for a full Red List assessment for which additional data are required, such as whether or not the taxon is severely fragmented or in continuing decline. However, this tool has been widely used in previous studies such as Romeiras et al. (2016) in which it was used to perform an IUCN Red List assessment of the Cape Verde endemic flora and to assist plant conservation in Macaronesia. As such, we decided to adapt the methodology for use in our study.

All these resources listed above, could potentially enable a qualitative assessment of the threat to individual *Restrepia* species, to be made by researchers not based in their ranges of occurrence. The genus has members ranging from those comparatively well-represented in herbaria databases to those with only one or two records and some with no records at all. The question as to how many records are required for an assessment is of great importance regarding some of these species, as the disparity between the more common and rarer members of the genus, might hinder the full use of these resources for *Restrepia*.

The purpose of the current study was twofold. Firstly, to assess whether currently available online resources could produce reliable evaluations of Red List Categories and Criteria to

For Peer Review Only

elucidate whether the quality of data available was adequate to produce realistic assessments for all *Restrepia* species. Secondly, to produce Red List assessments for the species present in this genus, for later inclusion on the IUCN Red List.

Materials and methods

The data presented in this paper are based upon an investigation carried out using GeoCAT in 2013.

Assembling the data set

An online search of 'Restrepia' through the GBIF data portal produced a data set of 753 occurrence records with many synonyms, duplicated entries, false entries (other genera with similar names) and entries with no collection and location data. Only entries with sufficient taxonomic (i.e. specific names) and geographical data (i.e. location, elevation description) were retained for later entry into the GeoCAT programme. Further online searches were made of the New York Botanic Gardens Herbarium (Ramirez et al. 2018), Tropicos (Tropicos 2018) and Kew Herbarium (RBG 2018) and details from Luer (1996a) were used to complete the data set. The resulting data set of 330 occurrence records contained the following fields: species name, collection year, location data (description only) and elevation. Not all fields were complete for every species. The descriptive location data were later used for entering species details into GeoCAT.

Data entry in GeoCAT

For Peer Review Only

Each occurrence point was georeferenced by comparing location descriptions with maps and gazetteers, using altitude details and other distribution details from Luer (1996a, b). Co-ordinates for each species were subsequently analysed in GeoCAT to calculate EOO and AOO for each species and in each of its countries of occurrence. The location data from GeoCAT were then examined in Google Earth to establish if forest cover persisted. Further calculations of EOO and AOO values were made, omitting locations where a visual inspection of Google Earth satellite imagery had indicated that forest cover no longer persisted.

Calculating Red List status

A complete Red List assessment involves evaluating data regarding a taxon against five criteria (A-E), any one of which may be used to determine the final threat category: population reduction, A; geographic range including EOO and AOO, B; small and declining population, C; small or restricted populations, D; and quantitative analysis of extinction probability, E (IUCN 2017). Regarding *Restrepia* species and the data available for the current investigation, only three of the criteria could be used to assess their level of threat: population reduction (criterion A), geographic range (criterion B) and very small or restricted population (criterion D).

Criterion A - Population reduction: The decline in population may be identified as "a decline, measured by % loss, in AOO, EOO and/or habitat quality" (IUCN 2017). By calculating the reduction in sub-populations, the decline in population for the entire range of the species, the decline in subpopulations in each country of distribution could be obtained. Criterion A2c "Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased or may not be understood or may not be reversible" (IUCN 2017) indicating a past reduction which had not ceased, was used to assess *Restrepia* species.

URL: http:/mc.manuscriptcentral.com/tped

For Peer Review Only

Criterion B - Geographic range: The geographic range for a species may be recorded as EOO or AOO. There are thresholds used to categorise the level of threat. Under this criterion, B1 and 2 (EOO and AOO), a (number of locations), and b (i,ii,iv) (continuing decline in any of EOO, AOO or number of locations) were used for assessment, according to IUCN guidelines (IUCN 2017).

Criterion D - Very small or restricted populations: Many *Restrepia* species are only known from a few collection localities and some have only been collected once. While these locations do not give any indication of the sub-population size, they may be used to assess D2, in the VU category only, which is based solely on the size of AOO and/or the number of locations where a threatening event is either happening or likely to happen. The numerical values used to assess the Criteria A, B and D for each *Restrepia* species are presented in Table 1.

Table 1 near here

Calculations, assessments and patterns of habitat loss

Using EOO and AOO values produced after correction for habitat loss, the percentage declines in EOO, AOO and location numbers were calculated. Each species was then subsequently evaluated against Criteria A, B and D, as previously. Maps were designed with the following – outline, physical features, major road(s), main towns, locations of national parks, reserves or private reserves and positions of *Restrepia* sub-populations, extinct and extant. From the position of the sub-populations for each country's indigenous *Restrepia* species it was possible to identify patterns in sub-population decline. A careful comparison was made of the position of remaining sub-populations to establish if they occurred in safe protected areas as this meant the immediate threat of loss of habitat was not present. Such sub-populations cannot be considered as threatened

For Peer Review Only

using Criterion A2. When assigning the final category of risk, the type of risk a species is facing is important, since the loss of habitat and pattern of habitat loss may occur variously through natural causes as well as through human activity. Finally, a summary of habitat loss in each country, together with a table of their native species and final Red List status was produced.

Results

Observations from Google Earth imagery

Historic Google Earth imagery for the geographical distribution of *Restrepia* from 1970 (the earliest Google Earth images) to 2013 indicated that during this time period the land use in many areas had changed primarily from forest to farming, with only scattered patches of the original forest remaining. This pattern of habitat loss was observed at many of the locations for *Restrepia* species and illustrates the rapid and extensive rate of deforestation and changes in land use throughout Central and South America. By contrasting the historical imagery (1970) with the satellite imagery for 2013 along the route of the Pan-American Highway the changes in land use that have occurred since the highway was completed could be clearly observed (Google Earth 2013a; Millner 2013). The maximum resolution of the imagery was 65 cm pan-sharpened, although in many places the available resolution was less. With recent changes in Google Earth the resolutions now range from 15 cm to 15 m.

Examples of the deforestation observed include habitat loss for *R. trichoglossa* in Central America (Google Earth 2013b) where land use is now primarily farming, as evidenced by fields and roads with a few fragmented patches of forest remaining. However, 38 out of the 55 original recorded locations for *R. trichoglossa* remain elsewhere. For *R. roseola* in Venezuela, at its only

URL: http:/mc.manuscriptcentral.com/tped

For Peer Review Only

recorded location (Google Earth 2013c), forest cover was observed to have been replaced by urban development and road building. *R. roseola* is probably extinct at this location in Venezuela, but other unrecorded subpopulations may persist elsewhere. Lastly, at one recorded location for *R. antennifera* in Colombia (Google Earth 2013d) from which habitat has been lost, much of the original forest has now changed to agricultural use and many roads have been built in the area. *R. antennifera* is a common species and there are still 19 out of the original 37 recorded locations remaining.

Statistical evaluation of the data set

Distribution graphs for a representative sample of the species are shown in Figure 3. *R. antennifera*, an example of a common and widespread species, has undergone substantial loss throughout its range with no remaining recorded locations in Peru. In contrast, *R. muscifera* has lost most locations in Central America and very few in Colombia and Ecuador. The final species, *R. citrina* has few recorded locations and has not lost any. Its global range is the same as its national range as it has only been recorded from one country.

Figure 3 near here

Calculation of EOO and AOO values with GeoCAT

The EOO and AOO values as calculated by GeoCAT, after amending for habitat loss, are included as supplementary data Table 1. After adjusting for habitat loss, the Red List status for AOO was either EN or CR. This had changed from EN to CR, if the number of remaining locations fell below three e.g. as is the case for *R. aspasicensis* and *R. cuprea.* The Red List status values for EOO values ranged from LC to CR e.g. *R. trichoglossa,* LC and *R. pandurata,* CR.

For Peer Review Only

Supplementary data Table 1 was used to produce the initial Red List assessments presented in supplementary data Table 2 together with the assessment amended for Criterion B.

Maps and accompanying tables

Table 2 near here

Figure 4 near here

Most locations assumed to be lost (shown in red) coincide with the route of the Pan American Highway, major towns and industrial areas in Venezuela, Colombia, Ecuador and Central America (Figure 4). The remaining locations (shown in blue) occur further away from the highway. Venezuela has 22 out of 40 locations remaining, all currently in protected areas such as national parks. This represents a loss of 45% of recorded locations, with 55% remaining for 15 species (Table 2). In Colombia and Ecuador, which have more *Restrepia* species (30 and 18 respectively), the overall loss of locations was estimated less. Colombia has 100 out of 138 locations remaining, with 46 of these in protected areas, which represents a loss of 28% of recorded locations for 30 species. Ecuador has 61 out of 96 locations remaining, with 36 in protected areas, representing a loss of 36% for 18 species (Table 2).

In Peru, the loss of locations does not coincide with the Pan-American Highway, as the highway does not follow the Andes, but was built along the coast. There are fewer endemic species occurring in this country (8 species) and 10 out of 17 locations remain, with six of these in protected areas. This represents a loss of 41% for these species (Table 2).

Central America can be divided into two areas for comparison - Mexico to Nicaragua and Costa Rica plus Panama. In Mexico to Nicaragua, there are fewer recorded locations for the *Restrepia*

For Peer Review Only

species *R. trichoglossa* and *R. muscifera,* but the loss of habitat has been very high. Only 4 out of 21 of the recorded locations remain, with two of these in protected locations; this represents a loss of 81% (Figures 6 A and B; Table 2). By contrast, in Costa Rica and Panama, 47 out of 68 recorded locations remain, with 22 of these in protected areas, which represents a loss of 32%. The highest loss occurs in one area in central Costa Rica, which coincides with several towns that are connected by the Pan American Highway (Figure 5B). In Panama, the highest loss was estimated to have occurred around Panama City and the industrial area around the Panama Canal (Figure 5B). Summary diagrams showing the percentages of threat to species occurring in each of their countries of origin is shown in Figure 6.

Figures 5 and 6 near here

GeoCAT and threat analysis

Since a category of threat may be assigned from any of the criteria (Table 1), an analysis of the highest Red List category obtained (supplementary data) provided an assessment of the degree of threat faced by each species. Every species achieved a Red List Category of 'Vulnerable' or above for its complete range. Apart from *R. trichoglossa* and *R. contorta*, all species could be classified as 'Threatened', with a Red List Category of 'Vulnerable', or above, in either one or more of their countries of origin (Table 2). *R. trichoglossa* is only of Least Concern in the parts of its range in Colombia and Ecuador, while *R. contorta* is of Least Concern in the part of its range in Colombia.

In Ecuador, one species, *R. trichoglossa,* is categorised as Least Concern and one species, *R. howei,* as Data Deficient. All remaining 16 species are threatened: one species, *R. ephippium,* is Critically Endangered; 20% are Endangered and 80% are Vulnerable. The results for the

URL: http:/mc.manuscriptcentral.com/tped

For Peer Review Only

distribution of *Restrepia* from this study correspond closely with the results of a Parsimony Analysis of Endemism (PAE) analysis carried out by field workers in Ecuador (Endara et al. 2007). This indicated that the majority of endemic orchids occurred in montane microhabitats between 1500 - 3000m, in the low montane and cloud montane forests, i.e. the same habitat and altitudes as identified for *Restrepia* from the initial data analysis. Only a small fraction of these species has been registered in the National System of Protected Areas (SNAP) in Ecuador. It is estimated that 85% of the endemic orchids of Ecuador are threatened: 2% are Critically Endangered, 11% are Endangered and 87% are Vulnerable (Endara et al. 2007).

In Colombia, out of 30 species found to occur there, one species, *R. fritillina,* was Data Deficient and two species, *R. trichoglossa* and *R. contorta* were considered of Least Concern, or not under threat. All the remaining species are threatened: 13% are Critically Endangered, 13% are Endangered and 63% are Vulnerable. When assigning the category Data Deficient and Not Evaluated it is important to note that this does not imply that the species concerned is/is not threatened, simply there is either too little data to make an assessment or that an assessment has not been carried out. For this reason, the species *R. piperitosa* (Peru), *R. howei* (Ecuador) and *R. fritillina* (Colombia) are all categorised as Data Deficient. It is not possible to assign a category of threat from the current data although it is probable that they may prove to be in a threatened category (at least Vulnerable, VU), as they are known from only a few locations.

In Venezuela, there are three species categorised as Extinct: *R. guttulata, R. aspasicensis* and *R. roseola.* Of these, *R. guttulata* is at the extreme limit of its range in Venezuela but is still found in Colombia as Endangered and in Ecuador as Vulnerable. *R. aspasicensis* also occurs in Colombia where it is Critically Endangered. *R. roseola* is only recorded from one location in Venezuela

URL: http:/mc.manuscriptcentral.com/tped

For Peer Review Only

although sub-populations may persist elsewhere in protected areas. All the remaining 12 species are threatened: 13% are Critically Endangered, 13% are Endangered and 63% are Vulnerable.

Peru is nearly at the southern limit of the distribution range for the genus. Fewer *Restrepia* species occur here and only two species are found further south in Bolivia. Of the nine species that have been found in Peru: two species, *R. antennifera* and *R. brachypus,* (both at the furthest extent of their respective ranges) are categorised as Extinct; *R. piperitosa* is categorised Data Deficient; *R. contorta* is categorised as Critically Endangered and *R. mohrii* as Endangered. The remaining four species (50% of those found here) are all categorised as Vulnerable.

In Bolivia, the only endemic species, *R. vasquezii* is categorised as Vulnerable. *R. brachypus,* known from two locations, is classified as Critically Endangered, but this may be better explained as this represents the limit of the range for this species, which is common in Colombia and Ecuador, although extinct in Peru.

The fewest number of *Restrepia* species are found in Central America. Only *R. muscifera, R. trichoglossa* and *R. aberrans* were previously recorded, although there are now five more species recorded in Guatemala. As there is so little data regarding *R. aberrans,* it could only be assigned the category D2VU (Vulnerable in Category D2) (Table 1). *R. aberrans* is arguably the rarest *Restrepia* and to date, few plants have found their way into collections and it is virtually unknown in cultivation. *R. muscifera* is not threatened in Costa Rica or Panama but is categorised as Endangered in Mexico to Nicaragua. *R. trichoglossa* is categorised as Vulnerable in Costa Rica and Panama and as Extinct in Mexico to Nicaragua. Habitat destruction in some of these countries has been especially high, and the few recorded locations for *R. trichoglossa* have been lost (Fig. 5, A and b).

URL: http:/mc.manuscriptcentral.com/tped

For Peer Review Only

Discussion

The initial possibility arose that increased road building and improved infrastructure after 1960 in the countries of origin may have led to the discovery of many new *Restrepia* and other orchid species. The maps (Figures 5 and 6) showing the species locations for *Restrepia* provide evidence for this. Locations where habitat had been lost (red points) were found to closely coincide with the route of the Pan American Highway in Central America, Colombia, Ecuador and to a lesser extent in Venezuela. In these countries, the route of the highway was through the valleys of the high Andes. The exception was in Peru, where the route of the highway runs along the coast where few *Restrepia* species have been found. The remaining locations (blue points) typically occur further away from the highway. The years during which the highway was built correspond with the dates of discovery for *Restrepia* species; i.e. most sections of the highway in South American countries were built between 1960 and 1975.

Deforestation and habitat loss were observed, via Google Earth satellite imagery, to have occurred along the route of the Pan American Highway throughout South America during the period 1970 - 2013 (Google Earth 2013a). For example, extensive changes in land use to agriculture were observed along a section of the highway in Colombia, evidenced by fields and the many minor roads joining the highway, built to open access to the surrounding countryside. In some areas, this deforestation has been very rapid, often over as short a time period as five years, as shown from the imagery. Road building has made many areas more easily accessible, not least to field biologists who have attempted to catalogue flora and fauna in these countries. In Ecuador, many orchid species have been discovered along Ecuador's road system (Endara et al. 2007; 2010), on roads that surround the National Parks (Endara et al. 2010). These examples provide an explanation as to why so many new *Restrepia* and other orchid species have been discovered

For Peer Review Only

since 1960. The areas in which they grow were inaccessible prior to this date and only became accessible due to the road building that accompanied that of the Pan American Highway.

National Parks

Many of the existing locations for *Restrepia* species were found to occur within national parks (Figures 5 and 6). Species in these locations may be thought of as 'safe' or at a reduced risk compared to those occurring elsewhere. This was important when assigning the final Red List status for these species. The number, type and area of national parks vary from country to country, and consequently, the numbers of species protected by them also vary. However, national park status may not be enough to protect these areas in the future (Cook 2004).

Table 3 near here

How many records are needed to give an accurate estimate of threat?

The above presents a rather bleak overview of the Red List Status for *Restrepia* species over their complete range; in which all species are classified as being under some degree of threat, one species as extinct, and 51 species as 'Threatened'. Unfortunately, this probably underestimates the degree of threat that some species face.

The probable cause of this arises when assessing Criterion B. Although GeoCAT will calculate AOO for species with one occurrence, the EOO must be considered as numerically equal to the AOO (IUCN, 2018). This results in GeoCAT assigning categories for EOO and AOO values as Critically Endangered. However, this Category for Criterion B cannot be assigned to these species as there are not enough data (i.e. more occurrences) from which to calculate values for the sub-

URL: http:/mc.manuscriptcentral.com/tped

For Peer Review Only

categories (a) and (b) (Table 1). These are needed for a full Red List Assessment of Criterion B. This adjustment for the final Criterion B assessment is shown in Tables 5 and 6. The most appropriate criterion available for these species is Criterion D2, even though GeoCAT had shown a Red List Status of Critically Endangered. For *Restrepia* species with one location this affects 20 out of 53 species across their entire range, 13 out of 30 species in Colombia, five out of 18 species in Ecuador, four out of 15 species in Venezuela, four out of nine species in Peru, one species in Bolivia and one species in Central America. All of these species could be classified as Critically Endangered, but this could not be done when current Red List guidelines were applied. The more recently discovered species in Guatemala - *R. mayana*, *R. archilae, R. cobanensis*, *(*Chiron and Szlachetko, 2013a,b,c,) and *R. valverdei* (Rodriguez and Véliz 2015) should seemingly be classified in a similar way. There is only one recorded location for them (Tropicos 2018) which would classify these four species as Vulnerable due to their small populations and distributions. The same is true of *R. nicolasii* Archila (Szlachetko and Chiron 2017) is listed in WCSP (2018) but not recorded in Tropicos (2018).

The Criterion D2 was intended to identify taxa with very small or restricted populations. A taxon qualifies for Vulnerable D2 if it's AOO and EOO are very limited (Table 1), and if there is a plausible, accompanying threat that would cause the taxon to become Critically Endangered or Extinct in a very short time period. Taxa with very limited AOO or EOO are particularly susceptible to such threat (IUCN 2018). However, it has been argued that the thresholds for AOO and the EOO, (Table 1) are frequently interpreted too literally the sub-criterion is too inclusive, resulting in extensive over-listing. It has also been argued that it is too exclusive, resulting in under-listing (IUCN 2018). For *Restrepia* species, however, an assessment of VU D2 should be considered an underestimation of the threat status of the species. It is indicative of a species,

For Peer Review Only

known from few recorded locations that is threatened by habitat loss. The level of this threat depends upon the exact known location of the species, being reduced for species in 'safe' areas and increased for those in 'unsafe' locations near urban areas or highways. An alternative view to the threat being underestimated might be that the AOO (and EOO to some extent) calculation is likely to be an underestimate due to insufficient survey data of the habitat. While more collections would provide more accurate data from which to calculate AOO and EOO, they could also provide data from which to further establish EN and CR categories.

A recent study (Brooks et al. 2019) has matched habitat and elevation data with remotely sensed land cover and elevation datasets to map the extent of suitable habitat (AOH) within the range of each species. This differs from the two spatial metrics (EOO and AOO) used in the IUCN Red List criteria for extinction risk assessment. AOH can be of value in locating target areas for species-specific field surveys, assessing the proportion of the habitat of a species within protected areas, and monitoring habitat loss and fragmentation. However, AOH is equivalent to neither EOO nor to AOO and thus cannot be compared directly (Brooks et al. 2019).

Even though the majority of *Restrepia* species have poorly known distributions, represented by few records, it has still been possible to make robust preliminary conservation assessments as shown in this investigation. Following the IUCN Red List guidelines, species known only from a single locality can be assessed depending on its current status and possible threats (Rivers et al. 2011). Although more data would be desirable, it is important to make assessments based on a limited number of records when these represent all the available information for a species (Rivers et al. 2011).

For Peer Review Only

Fortunately, for some of these narrow endemic species, large areas have been set aside as national parks in their countries of origin. When an occurrence for a species is within these areas, the risk may be substantially reduced. The worst example may be found in Mexico to Nicaragua which has lost 81% of *Restrepia* locations and only 10% remain in protected habitats. Colombia, Ecuador and Peru have similar percentages of *Restrepia* locations remaining in protected habitats. However, in Venezuela all the remaining locations for *Restrepia* species are in protected habitats which would suggest that these locations will remain safe in the future. Unfortunately, this cannot be relied upon, as there are great pressures in some countries to clear the currently protected areas for farming, building, mining and transport (Cook 2004). Critical problems include inappropriate forms of administration, political insecurity, encroachment, increasing human intervention and illegal activities (Tranel and Hall 2003).

Conclusions

The past decade has seen an increasing number of online resources with which to investigate conservation threats. This study has shown that it is currently possible to produce evaluations, in line with Red List categories, for the conservation status of *Restrepia* species using such resources (e.g. Tropicos, Kew Herbarium, GBIF, and GeoCAT). The problem concerning lack of accurate georeferenced collection data should be overcome by the proliferation of Global Positioning System (GPS) technology (El-Rabbany 2006) which is enabling field scientists to record location data accurately.

The use of these resources has enabled a detailed evaluation of the current threats to *Restrepia* species in the wild to be produced. Some taxa had only a few records, and the question arose as to the plausibility of making reliable assessments with these. Even these poorly documented taxa

URL: http:/mc.manuscriptcentral.com/tped

For Peer Review Only

could often be assigned a threat category by using background information concerning the deterioration of their habitat (IUCN 2018).

Restrepia has been shown to be an endangered genus comprising many narrow endemic species. The additional effects of global warming are likely to increase the degree of threat to *Restrepia* and other plant and animal species in Central and South America which occupy the same habitat.

The sixth mass extinction of species as a result of human activity (Holocene or Anthropocene extinction) is already having a major impact on orchids, in particular, on orchid genera indigenous to threatened environments (e.g. montane rain forests) such as *Restrepia*. Many Pleurothallid orchid genera are endemic in these areas e.g. *Stelis, Porroglossum, Dryadella, Masedvallia, Dracula, Platystele, Dracula* and *Pleurothallis*; all of which currently face the same environmental threats as *Restrepia,* given the widespread deforestation of these habitats.

Since 2013, when these data were first collected, deforestation has continued throughout Central and South America. As such, the current situation for these species is probably even worse than presented in our study. While the full extent of the effect on these populations remains unknown, this study has helped to reveal their Endangered status and the highly significant threats these orchids now face.

Ongoing work by the authors is building on the preliminary assessments carried out for this study, and they are in the process of documenting full global Red List assessments for later submission to and publication on the IUCN Red List, subject to reviews. This will further disseminate this information to the broader scientific and conservation community and will hopefully inform and facilitate future conservation of this genus.

For Peer Review Only

Declaration of interest

We hereby acknowledge that there is no financial interest or benefit that has arisen from the direct application of our research.

References

Armenteras D, Gast F, Villareal H. 2003. Andean forest fragmentation and the representativeness of protected natural areas in the eastern Andes, Colombia. Biol Conserv. 113: 245–256.

Bachman S, Moat J, Hill AW, de la Torre J, Scott B. 2011. Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool. In: Smith V, Penev L (Eds) e-Infrastructures for data publishing in biodiversity science. ZooKeys, 150: 117–126. doi: 10.3897/zookeys.150.2109

Baker C. 2007. Panama 3rd Ed. National Geographic Traveller. 272 pp.

Baker C. 2009. Costa Rica. National Geographic Traveller. 276 pp.

Benzing D. 1998. Vulnerabilities of Tropical Forests to Climate Change: The significance of resident epiphytes. Climate Change 39: 519–540.

Botanic Gardens Conservation International (BGCI). 2012. International Agenda for Botanic Gardens in Conservation: 2nd edition. BGCI, Richmond, UK

Brooks TM, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Rylands AB, Konstant WR, Flick P, Pilgrim J, Oldfield S, Magin G, Hilton-Taylor C. 2002. Habitat loss and extinction in the Hotspots of Biodiversity. Conserv Biol. 16: 909–923.

Brooks TM, Pimm SL, Akcakaya HR, Buchanan GM, Butchart SHM, Foden W, Hilton-Taylo C, Hoffman M, Jenkins CN, Joppa L, Li BV, Menon V, Ocampo-Penuele N, Rondinini C.

For Peer Review Only

2019. Measuring Terrestrial Area of Habitat (AOH) and Its Utility for the IUCN Red List. Trends in Ecol. and Evol. TREE 2566. 10pgs.

Bruinjzeel LA 2004 Hydrological functions of tropical forests: not seeing the soil for the trees? Agric. Ecosy and envir. 104: 185–228

Bubb P, May I, Miles L, Sayer J. 2004. Cloud forest agenda. UNEP World Conservation Monitoring Centre.

Calderón-Sáenz E. (ed.) 2007. Libro rojo de plantas de Colombia. Volumen 6, Orquídeas: primera parte. Instituto Alexander von Humboldt: Ministerio de Ambiente, Vivienda y Desarrollo Territorial, Bogotá, Colombia.

Chiron GR, Szlachetko DL. 2013a. Restrepia mayana Archila. Richardiana 13: 236

Chiron GR, Szlachetko DL. 2013b. Restrepia archilae. Richardiana 13: 237.

Chiron GR, Szlachetko DL. 2013c. Restrepia cobanensis. Richardiana 13: 238

Cook H. 2004. The end of the road, the Darien Jungle. International Journal of Wilderness 10:1

Corlett RT, Primack RB. 2011. Tropical Rain Forests, an ecological and biogeographical comparison, 2nd Edn. Wiley & Sons, Chichester, UK.

Cribb P, Govaerts R. 2005. Just how many Orchids are there? In: Raynal-Roques, A., Roguenant, A., and D. Prat. (eds.) Proceedings of the 18th World Orchid Conference, March 2005, Dijon, France. Naturalia Publications, pp 161–172.

Darbyshire I, Anderson S, Asatryan A, Byfield B, Cheek M, Clubbe C, Ghrabi Z, Harris T, Heatubun CD, Kalema J, Magassouba S, McCarthy B, Milliken W, de Montmollin B, Lughadha EN, Onana J, Saıdou D, Sarbu A, Shrestha K, Radford EA. 2017. Important Plant Areas: revised selection criteria for a global approach to plant conservation. Biodivers Conserv 26:1767–1800.

For Peer Review Only

El-Rabbany A. 2006. Introduction to GPS: The Global Positioning System, Second Edition. Artech House Publishers, Norwood, MA. 230 pp.

Endara L, León-Yánez S, Williams N. 2007. Patterns of endemism of the orchids of Ecuador: Conservation perspectives and priorities. In: Pridgeon AM and Suarez JP (eds.) Proceedings of the Second Scientific Conference on Andean Orchids. Universidad Técnica Particular de Loja, Loja, Ecuador. 127–147.

Endara L, Grimaldi DA, Bitty AR. 2010. Lord of the Flies: pollination of Dracula orchids. Lankesteriana 10(1): 1–11.

Fay MF, Krauss SL. 2003. Orchid conservation genetics in the molecular age. In: Dixon KW, Kell SP, Barrett RL, Cribb PJ (eds.) Orchid Conservation. Natural History Publications, Borneo.

Global Biodiversity Information Facility (GBIF). 2018. GBIF Data Portal [online]. Available at: http://data.gbif.org/welcome.htm. [Accessed 1st September 2018].

Global Land Cover Facility. 2018. TREE's project map - Hot spots of deforestation [online]. Previously available at : www.landcover.org. [Accessed 1st September 2018].

Google Earth. 2013a. Google Earth 7.02. Colombia 0º 41′49. 89″ S, 79º 27′47. 51″ W, elevation 138m. [online]. [Accessed January 2013]. Available at: http://www.google.co.uk/intl/en_uk/earth/index.htm.

--------- 2013b. Google Earth 7.02. Costa Rica 9º 58′59. 87″ N, 84º 11′41. 18″ W, elevation 921m. [online]. [Accessed January 2013]. Available at: http://www.google.co.uk/intl/en_uk/earth/index.htm.

For Peer Review Only

--------- 2013c. Google Earth 7.02. Venezuela 10º 21′22. 15″ N, 66º 57′49. 89″ W, elevation 1460m. [online]. [Accessed January 2013]. Available at: http://www.google.co.uk/intl/en_uk/earth/index.htm.

--------- (2013d) Google Earth 7.02. Colombia 0º 26′54. 90″ N, 78º 13′51. 59″ W, elevation 2815m. [online]. [Accessed January 2013]. Available at: http://www.google.co.uk/intl/en_uk/earth/index.htm.

Hassig SM, Quek Q. 2007. Panama 2nd Edn. Cavendish Square Publishing, New York, NY. 144pg.

Humboldt, Bonpland, Kunth. 1816. Nova Genera et species plantarum quas in peregrinatione ad plagam aequinoctialem orbis novi collegerent Bonpland et Humboldt. 7 vols., Paris, 1815–1825.

Inparques. 2018. National Institute of Parks. Available at: https://inparques.gob.ve/acera-de/ [Accessed 1st September 2018].

IUCN. 2012. International Union for Conservation of Nature. IUCN Red List Categories and Criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK: IUCN. iv + 32pp.

--------- 2017. Guidelines for Using the IUCN Red List Categories and Criteria. Version 13. Prepared by the Standards and Petitions Subcommittee [online]. Available at: https://www.iucnredlist.org/resources/redlistguidelines [Accessed 1st September 2018].

--------- 2018. The IUCN Red List of Threatened Species. Version 2018.2 [online]. Available at: http://www.iucnredlist.org. [Accessed 1st September 2018].

Kuper W, Kreft H, Nieder J, Koster N, Barthlott W. 2004. Large-scale diversity patterns of vascular epiphytes in Neotropical montane rain forests. J Biogeogr. 31:1477–1487.

For Peer Review Only

Lehman. 1901. Restrepia trichoglossa, Sanders' Orchid Guide, 215. Sanders, St. Albans.

León-Yánez S, Valencia R, Endara L, Pitman N, Ulloa C (eds.). 2011. The Red Book of the Endemic Plantá of Ecuador. Publications of QCA Herbarium, Pontifical Catohlic University of Ecuador, Quito, Ecuador.

Lindley J. 1859. Folia Orchidacea 8–9. London.

Luer CA. 1996a. Icones Pleurothallidinarum XIII, Systematics of the genus Restrepia (Orchidaceae). Monog Syst Botan. Missouri Botanical Gardens, St. Louis, MO.

-------- 1996b. Nuevas especies de Restrepia / New species of Restrepia. Orquideología 20:(2)117–182.

--------1998. Restrepia piperitosa. Monog Syst Botan. 65: 119. Missouri Botanical Gardens, St. Louis, MO.

--------2002. Restrepia portillae. Monog Syst Botan. 88:109. Missouri Botanical

--------2005. Restrepia howei. Monog Syst Botan. 103:279. Missouri Botanical Gardens, St. Louis, MO.

Luer CA, Rao VNM. 2007. Restrepia fritillina. Monog Syst Botan. 112: 110. Missouri Botanical Gardens, St. Louis, MO.

Maunder M, Culham A, Hankamer C. 1997. Picking up the pieces: Botanical conservation on degraded oceanic islands. In: Fiedler PL, Kareiva PM, (eds.) Conservation Biology: for the coming decade. Springer 2nd ed. pp. 333.

Millner H J. 2013. Reproductive biology and ex situ conservation of the genus Restrepia (Orchidaceae). Ph.D. dissertation, University of Wolverhampton, Wolverhampton, UK.

Mittermeier RA, Mittermeier CG, Myers N. 1999. Hotspots: earth's biologically richest and most endangered terrestrial ecoregions. CEMEX, Mexico City, Mexico.

For Peer Review Only

Mounce R, Smith P, Brockington S. 2017. Ex situ conservation of plant diversity in the world's botanic gardens. Nature Plants 3:795–802.

Myers N. 1988. Threatened Biotas: "Hotspots" in Tropical Forests. Environmentalist 8: 187–208.

-------- 1990. The Biodiversity Challenge: Expanded Hot-Spots Analysis. Environmentalist 10: 1243–256.

---------, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J. 2000. Biodiversity Hotspots: Threatened Species and Conservation Priorities. Nature 403: 853–858.

National Parks Worldwide. 2018a. National Parks System of Ecuador. Website www.nationalparks-worldwide.com [Accessed 1st September 2018].

--------- 2018b. National Parks of Peru. Website www.nationalparks-worldwide.com [Accessed 1st September 2018].

Parquesnacionales. 2018. National system of protected areas. Website www.parquesnacionales.gov.co/ [Accessed 1st September 2018].

Philips O. 1997. Biodiversity and Conservation of Neotropical Montane Forests: Proceedings of the Neotropical Montane Forest Biodiversity and Conservation Symposium, New York Botanical Garden 21-26 June 1993. Biodiversity and Conservation, 6: 8.

Ramirez J, Tulig M, Watson K, Thiers B. 2018. The New York Botanical Garden Herbarium (NY). Version 1.3. The New York Botanical Garden. Occurrence dataset https://doi.org/10.15468/6e8nje accessed via GBIF.org on 2018-11-26.

Reichenbach HG.1886. *Restrepia brachypus*. Flora 69:554.

Rivers MC, Taylor L, Brummitt NA, Meagher TR, Roberts DL, Lughadha EN. 2011. How many herbarium specimens are needed to detect threatened species? Biol Conserv. 144: 2541–2547.

For Peer Review Only

Rodriguez J, Véliz. 2015. *Restrepia valverdei* Archila. Moscosoa 19:15

Romeiras MM, Catarino S, Gomes I, Fernandes C, Costa JC, Caujapé-Castells J, Duarte MC. 2016. IUCN Red List assessment of the Cape Verde endemic flora: towards a global strategy for plant conservation in Macaronesia. Bot Journal Linnean Soc. 180:413–425.

Royal Botanical Garden, Kew (RBG). 2018. Herbarium Collections [online]. Available at: http://www.kew.org/collections/herbcol.html. [Accessed 1st September 2018].

Suman D. 2007. Development of an integrated coastal management plan for the Gulf of San Miguel and Darien Province, Panama: Lessons from the experience. Ocean and Coastal Management. 50:8 634–660.

Szlachetko DL, Chiron GR. 2017. *Restrepia nicolasii* Archila. Richardiana, n.s., 1: 3

Tranel MJ, Hall A. 2003. Parks as Battlegrounds: Managing Conflicting Values. In: Harmon DP and Putney AD (eds.) The Full Value of Parks: From Economics to the Intangible. Rowman & Littlefield, Lanham, Maryland, US. pp 253–267.

Tropicos. 2018. Missouri Botanical Garden [online]. Available at: http://www.tropicos.org. [Accessed 1st September 2018].

UNEP-WCMC. 2018. United Nations Environment Programme. World Conservation Monitoring Centre. Biodiversity and Ecosystems [online]. Available at: www.unep-wcmc.org. [Accessed 1st September 2018].

Whitmore TC. 2001. An Introduction to Tropical Rain Forests, 2nd edn. Oxford University Press.

World Checklist of Selected Plant Families (WCSP). 2018. Facilitated by the Royal Botanic Gardens, Kew [online]. Available at http://apps.kew.org/wcsp/. [Accessed 1st September 2018].

For Peer Review Only

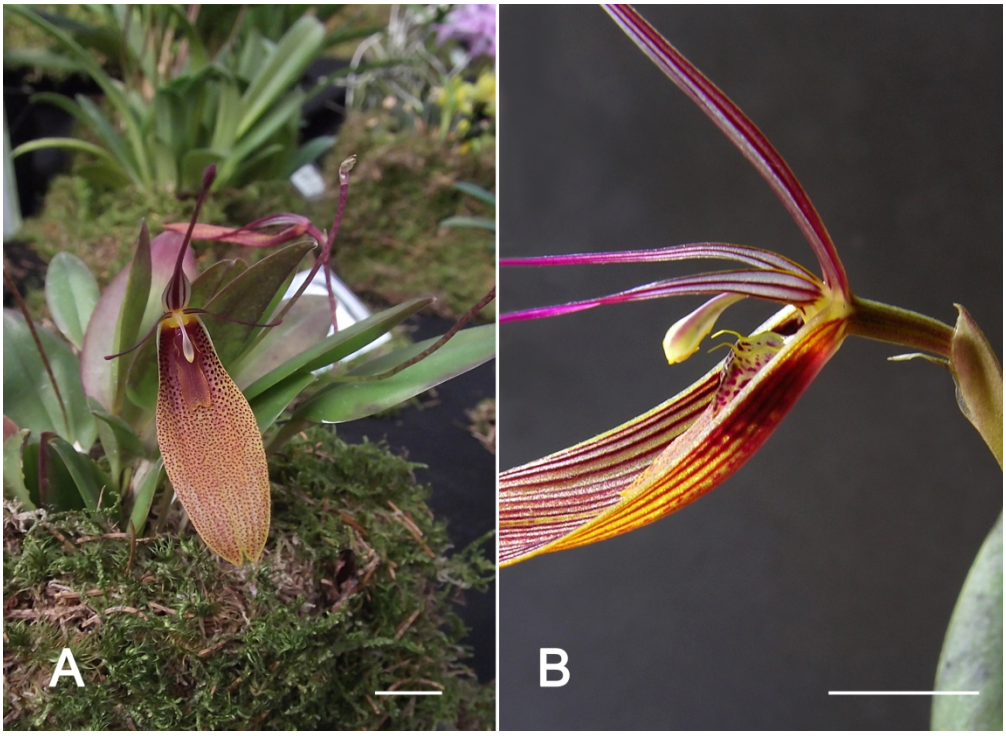

Fig. 1: (A) Ventral view Restrepia antennifera (Kunth, 1816) the type species for the genus (Humboldt et al., 1816). Discovered by Humboldt and Bonpland near Popáyan, Colombia, in 1801 (B) lateral view R. brachypus (Rchb.f. 1886). Scale bars = 5mm

204x148mm (300 x 300 DPI)

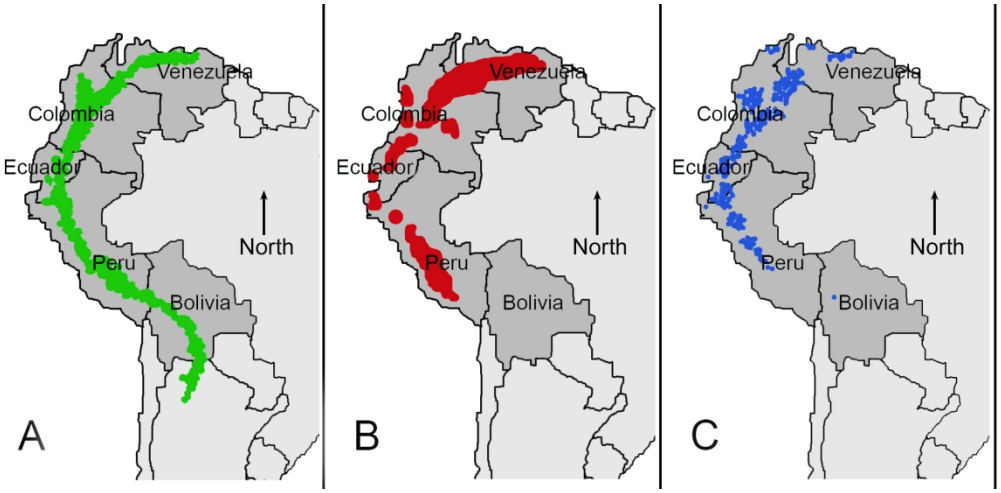

Fig. 2: Diagrams showing the distribution of montane forest, deforestation 'hot spots' and Restrepia species in South America

(A) Distribution of montane forest vegetation. Adapted from the Tropical Montane Forest map (UNEP-WCMC, 2018).

(B) 'Hot spots' of deforestation. Adapted from the TREE's project map, Global and Cover Facility, University of Maryland. (Global Land Cover Facility, 2018).

(C) Distribution of Restrepia species. Adapted from information in – Systematics of Restrepia (Orchidaceae) (Luer, 1996a).

170x82mm (300 x 300 DPI)

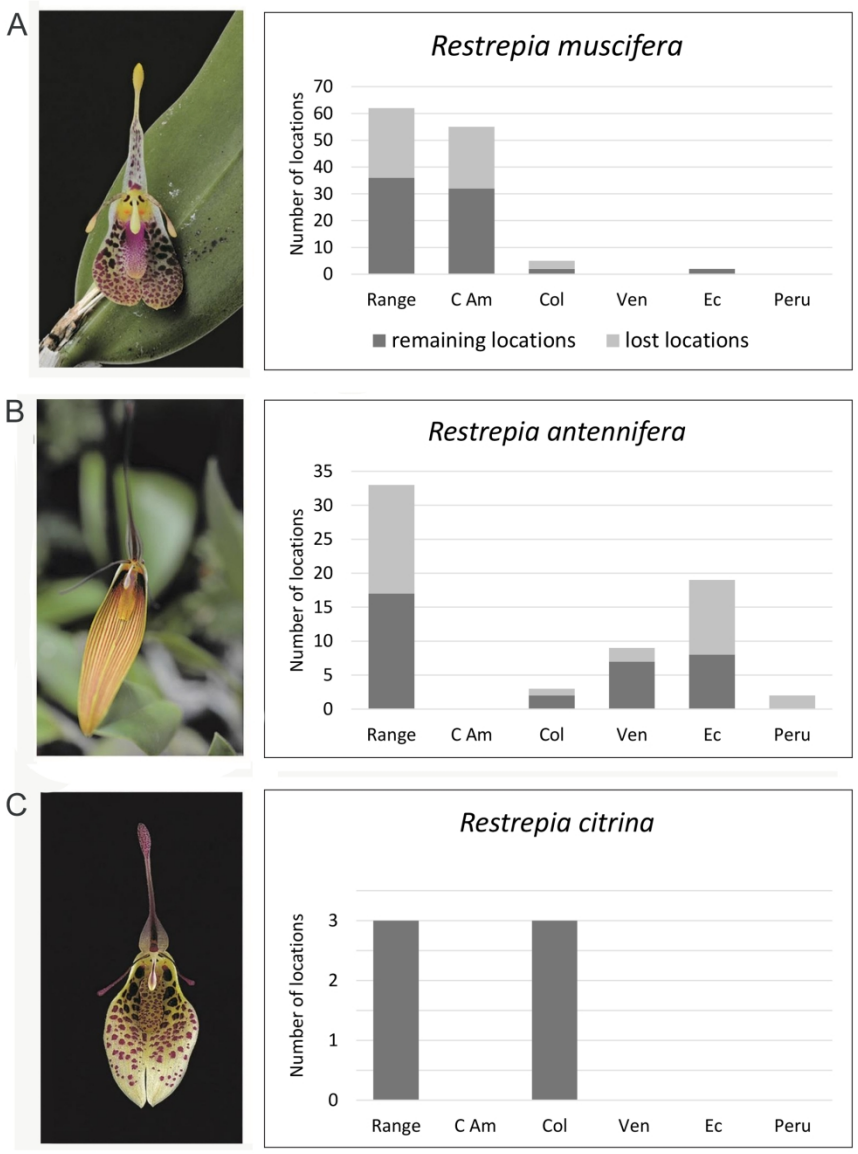

Fig. 3: Distribution graphs for some Restrepia species.

(A) R. antennifera, the type species for the genus, is a common species with a wide distribution in S. America. Although many of its locations remain, it has undergone substantial habitat loss throughout its range.
(B) R. muscifera is common in Central America where 32/55 locations remain, a substantial loss of approximately 40%. It is less common in Colombia and Ecuador where it has undergone less loss.
(C) R. citrina, a narrow endemic species with few recorded locations from Colombia. In contrast, this species has not undergone recorded habitat loss, one explanation being that it was discovered within a very limited range and within protected areas, such as nature reserves.

179x243mm (300 x 300 DPI)

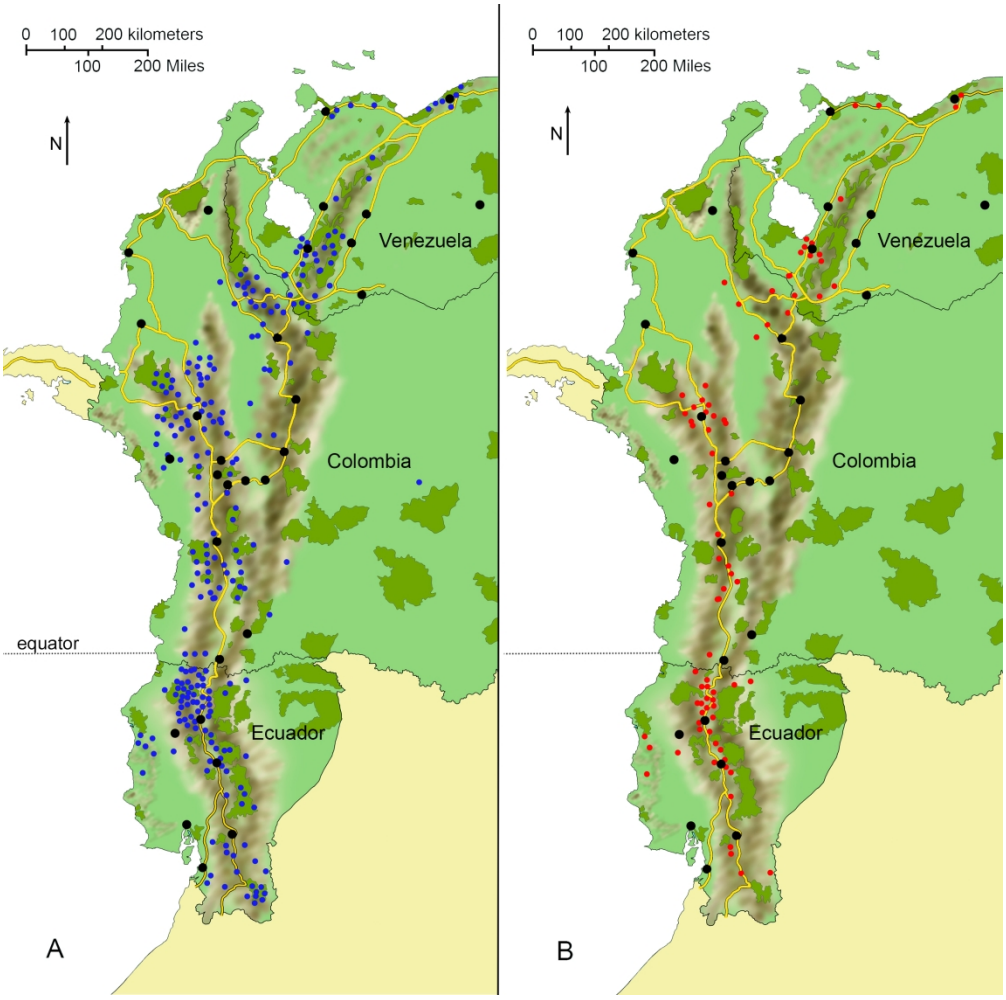

Fig. 4: Restrepia location loss along the Pan American Highway in South America.
Key: yellow - Pan American Highway, larger black dots - main towns, blue dots - locations where Restrepia species were discovered, red dots – locations where forest cover no longer persists.
Land mass of Venezuela, Colombia and Ecuador shown in green, with areas set aside as Nature reserves, National Parks as a darker green.
The Andean mountain range is illustrated in brown and beige shading.
Map A locations where Restrepia species were discovered.
Map B locations where forest cover was observed in Google Earth to no longer persist. These locations occur mainly along the route of the Pan American Highway (shown in yellow) in these countries.
Originally a road planned to link North and South America, the Pan American Highway has today become a network of roads covering thousands of miles. Much of the original road building was carried out in the 1940's and 50's with extensive improvement in the late 1960's. The resulting changes in land use have had a great impact on the endemic orchid species of these Andean regions. In Venezuela 45% loss, in Colombia 28% loss and in Ecuador 36% loss of recorded Restrepia locations have occurred.

211x209mm (300 x 300 DPI)

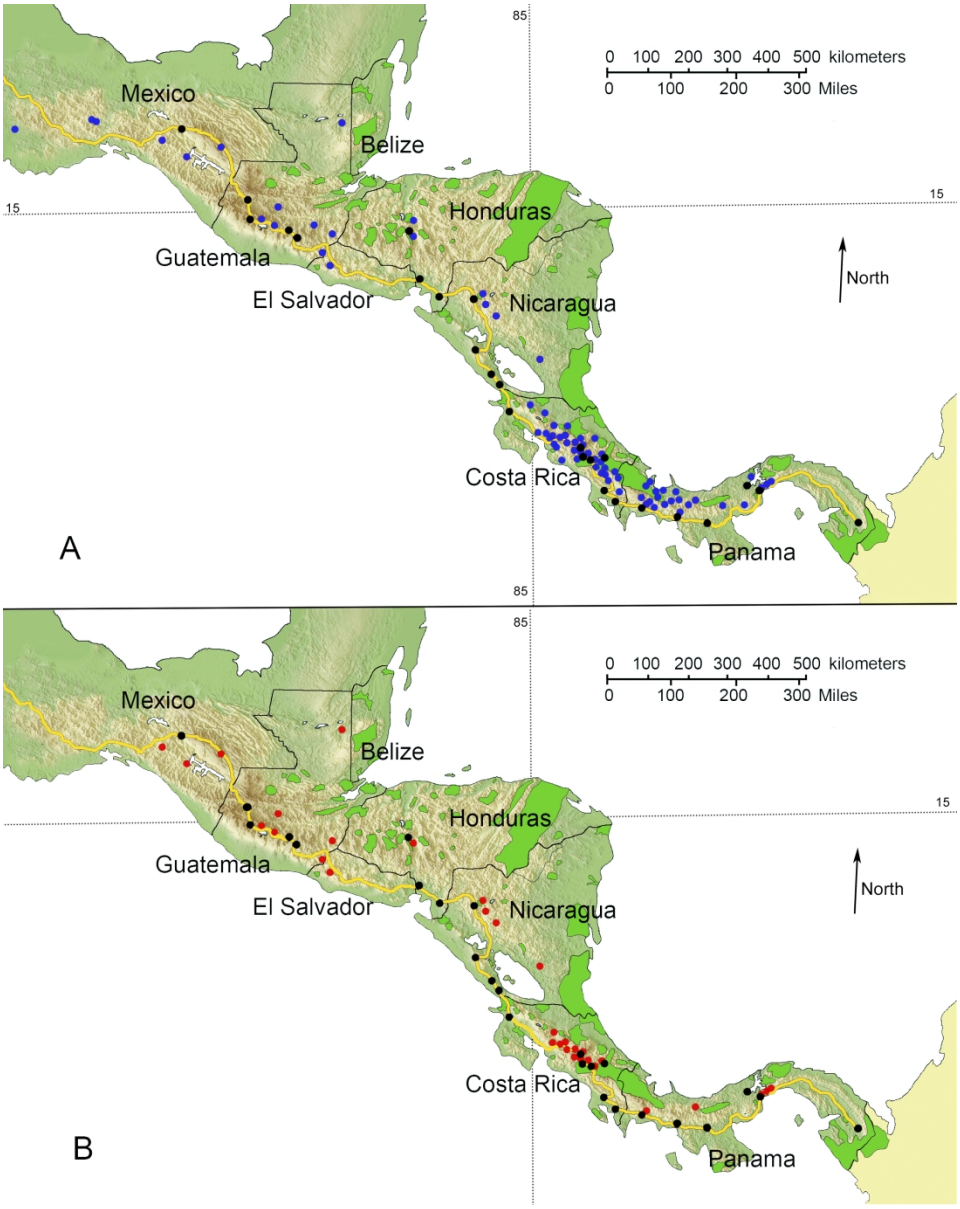

Fig. 5: Restrepia location loss along the Pan American Highway in Central America.
Key: yellow - Pan American Highway, larger black dots - main towns, blue dots - locations where Restrepia species were discovered, red dots – locations where forest cover no longer persists.
Map A shows the distribution of the locations where Restrepia species were
Map B shows the locations where forest cover no longer persists - as observed in Google Earth . There locations occur mainly along the route of the Pan American Highway. In Mexico to Nicaragua, forest cover has been lost for the few discoveries made there. In Costa Rica and Panama, and while there are many locations remaining there has been a substantial loss of forest cover for some locations.

209x263mm (300 x 300 DPI)

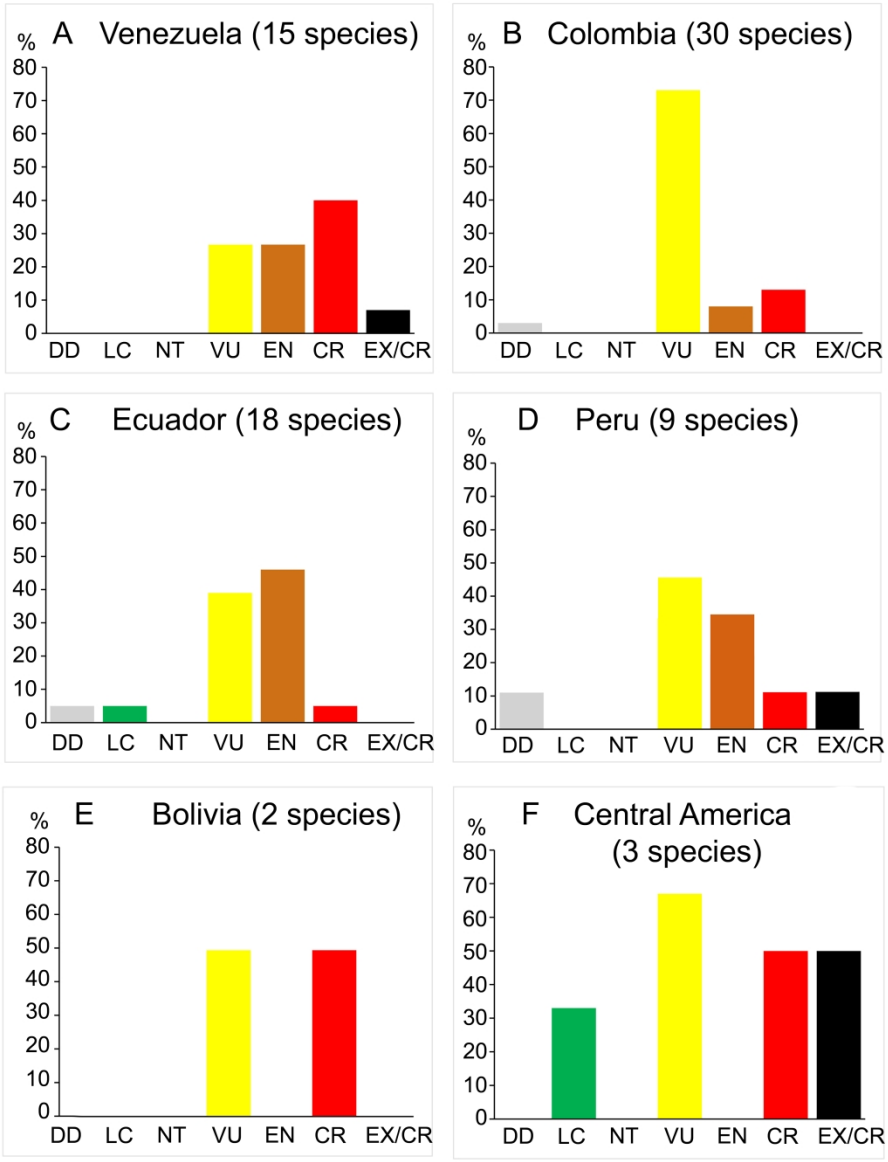

Fig. 6: Summary of the Categories of Risk facing Restrepia species in South and Central American countries. Colour key and abbreviations correspond to that for the Endangered Categories produced by the IUCN DD Date deficient, LC Least Concern, NT Near Threatened, VU Vulnerable, EN Endangered, CR Critically Endangered, EX Extinct in the Wild (these are always capitalised as shown).
All species, except one should be regarded as Vulnerable or above at some point in their range. However, this should be considered as an underestimation of threat faced by these species as there was only enough data available to assess the potentially most vulnerable species as VU and the categories of EN or CR could not be assigned.
In Central America the bars LC and VU show the category of risk facing R. trichoglossa, R. muscifera and R. aberrans in Costa Rica and Panama, while the bars CR and EX/CR illustrate the contrasting risk facing these species in countries from Mexico to Nicaragua.
R. trichoglossa is Extinct in Mexico to Nicaragua but is Vulnerable in Costa Rica and Panama. R. muscifera is Least Concern in Costa Rica and Panama, but EN/CR in Mexico to Nicaragua, see also Table 5.
Overall percentages of the Categories of Risk facing the species in the genus across their complete

geographical range: DD 6%, VU 58%, EN 17%, CR 17 %, EX 2 %. Recent species discoveries in Guatemala would alter this slightly. These, from data currently available, would only qualify to be categorised as Vulnerable.

190x247mm (600 x 600 DPI)

Table 1: Criteria used to assess the Red list status of *Restrepia* species

	Critically Endangered CR	Endangered EN	Vulnerable VU
A2: (c) Population reduction observed, estimated or inferred	≥ 80%	≥ 50%	≥ 30%
B1: EOO[1]	< 100 km²	< 5,000 km²	< 20,000 km²
B2: AOO[2]	< 10 km²	< 500 km²	< 2,000 km²
but for Criterion B1 or 2 to be awarded these must also include:			
a: number of locations	1	≤ 5	≤ 10
b: continuing decline in either -	(i) EOO; (ii) AOO or (iv) number of locations		
D2			AOO <20 km² No. of locations ≤ 5

[1]EOO Extent of Occurrence; [2]AOO Area of Occupation

The Criteria and numerical thresholds used to establish the Red List status for *Restrepia* species in the current study. Only Criterion A, population reduction, and Criteria B1 (EOO) and B2 (AOO) could be assessed from the available data. Criteria B1 or B2 could only be awarded if - (a) number of locations and (b) continuing decline in either EOO or AOO, could be established as well. Many species could only be classified as D2, Vulnerable, because there was insufficient data to establish B1, 2, (a) and (b). This has resulted in a potential underestimation of threat to these species.

For Peer Review Only

Table 2: Remaining species locations and Red List assessment amended where appropriate for lower risk associated with protected habitat shown for each country.

Restrepia species	Original number of locations[1]	Total number locations remaining[2]	Locations remaining in protected areas[3]	Final assessment amended for safe habitat[4]			Final Red List value[5]
				Criteria:			
				A	B	D	
Venezuela (15 species)							
Species with lost locations/habitat loss							
antennifera	3	2	2		CR	VU	**CR**
aristulifera	6	3	3		EN	VU	**EN**
aspasiensis	1	0	0			EX	**EX**
contorta	6	1	1			VU	**VU**
elegans	5	3	3		EN	VU	**EN**
guttulata	1	0	0			EX	**EX**
jesupiana	4	2	2		CR	VU	**CR**
pelyx	2	1	1		CR	VU	**CR**
renzii	2	1	1		CR	VU	**CR**
roseola	1	0	0			EX	**EX**
Species that have not lost locations							
lansbergii		2	2		CR	VU	**CR**
radulifera		1	1			VU	**VU**
sanguinea		3	3			VU	**VU**
trichoglossa		1	1			VU	**VU**
wagnerii		2	2			VU	**VU**
Colombia (30 species)							
Species with lost locations/habitat loss							
antennifera	9	7	5		EN		**EN**
aristulifera	3	2	2		CR	VU	**CR**
aspasiensis	2	1	1		CR		**CR**
brachypus	23	16	3	VU			**VU**
contorta	18	13	5		EN		**EN**
cuprea	4	2	1	CR	CR	VU	**CR**
echo	10	8	2		EN		**EN**

For Peer Review Only

guttulata	16	9	5	EN	EN		**EN**
muscifera	5	2	2		CR	VU	**CR**
nittiorhyncha	3	1	0	CR	CR	VU	**CR**
pelyx	3	2	1	VU	CR	VU	**CR**
sanguinea	6	4	4		EN	VU	**EN**
trichoglossa	12	10	5	LC	LC	LC	**LC**
teaguei	2	2	1			VU	**VU**

Species that have not lost locations

chameleon		1	1			VU	**VU**
chocoensis		3	0			VU	**VU**
chrysoglossa		1	1			VU	**VU**
citrina		3	1			VU	**VU**
echinata		1	0			VU	**VU**
escobariana		1	0			VU	**VU**
falkenbergii		3	1			VU	**VU**
flosculata		1	0	EN	CR	VU	**CR**
limbata		2	2			VU	**VU**
metae		1	0			VU	**VU**
pandurata		1	0			VU	**VU**
purpurea		1	0			VU	**VU**
seketii		1	1			VU	**VU**
tabeae		1	1			VU	**VU**
tsubotae		1	1			VU	**VU**
*fritillina**						DD	**DD**

Ecuador (18 species)

Species with lost locations/habitat loss

antennifera	19	8	5	VU	VU		**VU**
brachypus	15	8	5	VU	EN		**EN**
contorta	9	5	4		EN	VU	**EN**
dodsonii	11	5	2	VU	VU	VU	**VU**
ephippium	3	2	2		CR	VU	**CR**
flosculata	4	3	2		EN	VU	**EN**
guttulata	9	6	6		EN		**EN**
iris	5	4	1	VU	EN	VU	**EN**
lansbergii	3	2	1		CR	VU	**CR**

Species that have not lost locations

condorensis		3	1			VU	**VU**

For Peer Review Only

cymbula		1	1			VU	**VU**
mendozae		1	0			VU	**VU**
muscifera		2	2			VU	**VU**
persiciana		1	1			VU	**VU**
portillae		1	0			VU	**VU**
schizosepala		1	1			VU	**VU**
trichoglossa		8	2			LC	**LC**
*howei**						DD	**DD**

Peru (9 species)

Species with lost locations/habitat loss

antennifera	2	0	0		CR	VU	**CR**
brachypus	1	0	0			EX	**EX**
contorta	6	3	1		EN	VU	**EN**
mohrii	3	2	1	EN	EN	VU	**EN**

Species that have not lost locations

cloesii		1	1			VU	**VU**
echinta		2	2			VU	**VU**
guttulata		1	1			VU	**VU**
lansbergii		1	1			VU	**VU**
*piperitosa**						DD	**DD**

Bolivia (2 species)

Species with lost locations/habitat loss

vasquezii	4	4	2			VU	**VU**
brachypus	2	1	0	CR	CR	VU	**CR**

Central America (8 species)

Species with lost locations/habitat loss

muscifera							
Com. range	55	32	12			VU	**VU**
Mex to Nic	19	4	2	EN	EN	VU	**EN**
C. Rica and Pan	36	28	10	LC	LC	LC	**LC**
trichoglossa							
Com. range	34	19	10			VU	**VU**
Mex to Nic	2	0	0			EX	**EX**
C. Rica and Pan	32	19	12			VU	**VU**

For Peer Review Only

Species that have not lost locations					
aberrans	1	1	1	VU	**VU**
Newly discovered species from Guatemala[7]					
archilae					**VU**
cobanensis					**VU**
mayana					**VU**
nicolasii					**VU**
valverdii					**VU**

The table shows the distribution of species in each of their countries of origin in Central and South America. The centres of diversity in South America, Colombia (30 species) and Ecuador (18 species) are evident with the highest numbers of recorded species. The habitat loss in Central America for the species *R. muscifera* and *R. trichoglossa* is indicated by the fact that most locations for these species now remain in Costa Rica and Panama. The newly discovered species in Guatemala are included, although only assessed as VU due to insufficient data to award any other category.

[1]Original number of recorded locations. [2]The total remaining number of locations where forest cover remained. [3]Any of the remaining locations found to occur in safe habitat e.g. National Parks or nature reserves. [4]Final Red List assessment after reducing level of threat when any locations were in safe habitats (see also Table 3). [5]Final Red List assessment after all amendments had been made (see also Table 3). Species marked * are Data Deficient (DD) due to no accurate data being available regarding their distribution and/or recorded locations.

For Peer Review Only

Table 3: National Parks and protected areas in Central and South America

Country	Protected areas	% of country	Reference
Venezuela	43 national parks	21.8	National Institute of Parks (Inparques) 2018
Colombia	56 national protected areas	>10	Parquesnacionales 2018
Ecuador	30 national parks	17	National Parks Worldwide 2018a
Peru*	61 natural protected areas	15.21	National Parks Worldwide 2018b
Costa Rica	26 national parks	25	Baker 2009
Panama	designated national parks	30	Baker 2007

Notes:

The types of protection provided vary from natural protected areas to designated national parks. The status of these areas is often threatened due to the discovery of natural resources and the need to increase land available for farming.

*the land area (30%) designated as national parks in Peru includes the Darién gap, the last remaining area of pristine rain forest on the Panama/Colombia border (Hassig and Quek 20007; Suman, 2007).

For Peer Review Only

Table 1: Original number of locations, percentage decrease in locations, EOO and AOO values and corresponding status as calculated by GeoCAT.

species	origin	original number of locations	% loss	E00 % decrease in km²	EOO STATUS	AOO % decrease in km²	AOO STATUS
R. aberrans	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**CR**
	C. America	1	0	0.0	CR	0.0	CR
R. antennifera	**Range**	**37**	**49**	**10.1**	**LC**	**48.6**	**EN**
	Venezuela	3	33	76.7	CR	33.3	EN
	Colombia	9	22	1.6	LC	22.2	EN
	Ecuador	19	58	16.2	NT	57.9	EN
	Peru	3	33	97.5	CR	33.3	EN
R. aristulifera	**Range**	**9**	**44**	**52.7**	**EN**	**44.4**	**EN**
	Venezuela	6	50	72.8	EN	50.0	EN
	Colombia	3	33	66.7	CR	33.3	CR
R. aspasiensis*	**Range**	**3**	**67**	**99.5**	**CR**	**66.7**	**CR**
	Venezuela	1	100	100.0			
	Colombia	2	50	50.0	CR	50.0	CR
R. brachypus*	**Range**	**41**	**39**	**28.7**	**LC**	**41.5**	**EN**
	Colombia	23	30	30.3	LC	30.4	EN
	Ecuador	15	47	25.9	NT	46.7	EN
	Peru	1	100				
	Bolivia	2	50	50.0	CR	50.0	CR
R. chameleon	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**CR**
	Colombia	1	0	0.0	CR	0.0	CR
R. chocoensis	**Range**	**3**	**0**	**0.0**	**CR**	**0.0**	**EN**
	Colombia	3	0	0.0	CR	0.0	EN
R. chrysoglossa	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**CR**
	Colombia	1	0	0.0	CR	0.0	CR
R. citrina	**Range**	**3**	**0**	**0.0**	**CR**	**0.0**	**EN**
	Colombia	3	0	0.0	CR	0.0	EN
R. cloesii	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**CR**
	Peru	1	0	0.0	CR	0.0	CR

For Peer Review Only

R. condorensis	**Range**	**3**	**0**	**0.0**	**CR**	**0.0**	**EN**
	Ecuador	3	0	0.0	CR	0.0	EN
R. contorta	**Range**	**39**	**44**	**20.9**	**LC**	**43.6**	**EN**
	Venezuela	6	83	100.0	CR	83.3	CR
	Colombia	18	28	5.4	LC	27.8	EN
	Ecuador	9	44	91.6	EN	44.4	EN
	Peru	6	50	83.9	EN	50.0	EN
R. cuprea	**Range**	**4**	**50**	**99.6**	**CR**	**50.0**	**CR**
	Colombia	4	50	99.6	CR	50.0	CR
R. cymbula	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**EN**
	Ecuador	1	0	0.0	CR	0.0	EN
R. dodsonii	**Range**	**11**	**55**	**56.9**	**EN**	**54.5**	**EN**
	Ecuador	11	55	56.9	EN	54.5	EN
R. echinata	**Range**	**3**	**0**	**0.0**	**LC**	**0.0**	**EN**
	Colombia	1	0	0.0	CR	0.0	CR
	Peru	2	0	0.0	CR	0.0	CR
R. echo	**Range**	**10**	**20**	**4.9**	**VU**	**20.0**	**EN**
	Colombia	10	20	4.9	VU	20.0	EN
R. elegans	**Range**	**5**	**40**	**31.1**	**VU**	**40.0**	**EN**
	Venezuela	5	40	31.1	VU	40.0	EN
R. ephippium	**Range**	**3**	**33**	**42.9**	**CR**	**33.3**	**CR**
	Ecuador	3	33	42.9	CR	33.3	CR
R. escobarina	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**CR**
	Colombia	1	0	0.0	CR	0.0	CR
R. falkenbergii	**Range**	**3**	**0**	**0.0**	**EN**	**0.0**	**EN**
	Colombia	3	0	0.0	EN	0.0	EN
R. flosculata	**Range**	**5**	**20**	**31.5**	**EN**	**42.9**	**E**
	Colombia	1	0	0.0	CR	0.0	CR
	Ecuador	4	25	48.2	EN	25.0	EN
R. guttulata*	**Range**	**27**	**41**	**50.5**	**LC**	**42.9**	**EN**
	Venezuela	1	100	100.0			
	Colombia	16	44	66.8	LC	50.0	EN
	Ecuador	9	33	4.1	VU	33.3	EN
	Peru	1	0	0.0	CR	0.0	CR
R. iris	**Range**	**5**	**20**	**56.6**	**EN**	**20.0**	**EN**
	Ecuador	5	20	56.6	EN	20.0	EN
R. jesupiana	**Range**	**4**	**50**	**98.5**	**CR**	**50.0**	**CR**

For Peer Review Only

	Venezuela	4	50	98.5	CR	50.0	CR
R. lansbergii	**Range**	**6**	**17**	**12.3**	**LC**	**0.0**	**EN**
	Venezuela	2	0	68.8	CR	33.3	CR
	Ecuador	3	33	99.3	CR	33.3	EN
	Peru	1	0	0.0	CR	0.0	CR
R. limbata	**Range**	**2**	**0**	**0.0**	**CR**	**0.0**	**CR**
	Colombia	2	0	0.0	CR	0.0	CR
R. mendozae	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**CR**
	Ecuador	1	0	0.0	CR	0.0	CR
R. metae	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**CR**
	Colombia	1	0	0.0	CR	0.0	CR
R. mohrii	**Range**	**3**	**33**	**98.6**	**EN**	**33.3**	**EN**
	Peru	3	33	98.6	EN	33.3	EN
R. muscifera	**Range**	**62**	**40**	**1.4**	**LC**	**41.9**	**EN**
	Cen. America	55	42	0.9	LC	41.8	EN
	Colombia	5	60	99.9	CR	60.0	CR
	Ecuador	2	0	65.2	CR	0.0	CR
R. nittiorhyncha	**Range**	**3**	**67**	**99.9**	**CR**	**66.7**	**CR**
	Colombia	3	67	99.9	CR	66.7	CR
R. pandurata	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**CR**
	Colombia	1	0	0.0	CR	0.0	CR
R. pelyx	**Range**	**5**	**40**	**70.8**	**VU**	**50.0**	**EN**
	Venezuela	2	50	50.0	CR	50.0	CR
	Colombia	3	33	98.7	CR	33.3	EN
R. purpurea	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**CR**
	Colombia	1	0	0.0	CR	0.0	CR
R. radulifera	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**CR**
	Venezuela	1	0	0.0	CR	0.0	CR
R. renzii	**Range**	**2**	**50**	**50.0**	**CR**	**50.0**	**CR**
	Venezuela	2	50	50.0	CR	50.0	CR
R. roseola*	**Range**	**1**	**100**				
	Venezuela	1	100				
R. sanguinea	**Range**	**9**	**33**	**3.7**	**LC**	**33.3**	**EN**
	Venezuela	3	0	0.0	EN	0.0	EN
	Colombia	6	50	27.5	VU	50.0	EN
R. schizosepala	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**CR**

For Peer Review Only

	Ecuador	1	0	0.0	CR	0.0	CR
R. seketii	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**CR**
	Colombia	1	0	0.0	CR	0.0	CR
R. tabeae	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**CR**
	Colombia	1	0	0.0	CR	0.0	CR
R. teaguei	**Range**	**2**	**0**	**0.0**	**CR**	**50.0**	**8**
	Ecuador	2	0	0.0	CR	0.0	CR
R. trichoglossa	**Range**	**55**	**31**	**44.4**	**LC**	**30.9**	**EN**
	Central America	34	44	91.2	VU	44.1	EN
	Venezuela	1	0	0.0	CR	0.0	CR
	Colombia	12	17	25.4	NT	16.7	EN
	Ecuador	8	0	0.0	NT	0.0	EN
R. tsubotae	**Range**	**1**	**0**	**0.0**	**CR**	**0.0**	**CR**
	Colombia	1	0	0.0	CR	0.0	CR
R. vasquezii	**Range**	**4**	**0**	**0.0**	**VU**	**0.0**	**EN**
	Bolivia	4	0	0.0	VU	0.0	EN
R. wagnerii	**Range**	**2**	**0**	**0.0**	**EN**	**0.0**	**EN**
	Venezuela	2	0	0.0	EN	0.0	EN
R. piperitosa[a]	*Peru*	1					
R. portillae[a]	*Ecuador*	1	0	0.0	CR	0.0	CR
R. howeii[a]	*Ecuador*	1					
R. persiciana[a]	*Ecuador*	1	0	0.0	CR	0.0	CR
R. fritillina[a]	*Colombia*	1					

The 'Range' indicates values across the entire geographic range for a species – global values

The species marked * have lost all the locations in one part of their range, although they may be common elsewhere (*R. brachypus, R. guttulata*) or they appear to be extinct in part of their range (*R. aspasiencis*) or extinct at the only recorded locations (*R. roseola*).

The species marked [a] have very little collection data, having been discovered since 2000; their national distributions are the same as their global distributions.

For Peer Review Only

Table 2: Stages in formulating the Red List assessment for *Restrepia* species.

species	origin	Initial Red List assessment[1]			After amending for Criterion B[2]			After amending for safe habitat[3]			Final Red List value
		Criteria:			Criteria:			Criteria:			
		A	B	D	A	B	D	A	B	D	
R.aberrans	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	C. America		CR	VU			VU			VU	**VU**
R. antennifera	**Range**	**VU**	**EN**		**VU**			**VU**			**VU**
	Venezuela	EN	CR	VU	EN	CR	VU		CR	VU	**CR**
	Colombia		EN			EN			EN		**EN**
	Ecuador	CR	CR	VU	EN	EN		VU	VU		**VU**
	Peru	EN	CR	VU	EN	CR	VU	EX	EX		**EX**
R. aristulifera	**Range**	**VU**	**EN**	**VU**	**VU**	**EN**	**VU**		**CR**	**VU**	**CR**
	Venezuela	EN	CR	VU	EN	EN	VU		EN	VU	**EN**
	Colombia	EN	CR	VU	EN	CR	VU		CR	VU	**CR**
R. aspasiensis	**Range**	**CR**	**CR**	**VU**	**CR**	**CR**	**VU**		**CR**	**VU**	**CR**
	Venezuela	CR			CR			EX	EX		**EX**
	Colombia	CR	CR		CR	CR			CR		**CR**
R. brachypus	**Range**	**VU**	**EN**		**VU**			**VU**			**VU**
	Colombia	VU	EN		VU			VU			**VU**
	Ecuador	VU	EN		VU	EN		VU	EN		**VU**
	Peru	CR	CR		CR			EX	EX		**EX**
	Bolivia	CR	CR	VU	CR	CR	VU	CR	CR	VU	**CR**
R. chameleon	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Colombia		CR	VU			VU			VU	**VU**
R. chocoensis	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Colombia		CR	VU			VU			VU	**VU**
R. chrysoglossa	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Colombia		CR	VU			VU			VU	**VU**
R. citrina	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Colombia		CR	VU			VU			VU	**VU**
R. cloesii	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Peru		CR	VU			VU			VU	**VU**
R. condorensis	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Ecuador		CR	VU			VU			VU	**VU**
R. contorta	**Range**	**VU**	**EN**		**VU**			**VU**			**VU**

For Peer Review Only

	Venezuela	CR	CR	VU	CR		VU			VU	**VU**
	Colombia		LC			LC			LC		**LC**
	Ecuador	CR	EN	VU	CR	EN	VU		EN	VU	**EN**
	Peru	CR	EN	VU	CR	EN	VU		EN	VU	**EN**
R. cuprea	**Range**	**CR**	**CR**	**VU**	**CR**	**CR**	**VU**	**CR**	**CR**	**VU**	**CR**
	Colombia	CR	CR	VU	CR	CR	VU	CR	CR	VU	**CR**
R. cymbula	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Ecuador		CR	VU			VU			VU	**VU**
R. dodsonii	**Range**	**CR**	**CR**	**VU**	**CR**	**CR**	**VU**	**VU**	**VU**	**VU**	**VU**
	Ecuador	CR	CR	VU	CR	CR	VU	VU	VU	VU	**VU**
R. echinata	**Range**		**EN**	**VU**			**VU**			**VU**	**VU**
	Colombia		CR	VU			VU			VU	**VU**
	Peru		CR	VU			VU			VU	**VU**
R. echo	**Range**		**EN**			**EN**			**EN**		**EN**
	Colombia		EN			EN			EN		**EN**
R. elegans	**Range**		**EN**	**VU**		**EN**	**VU**		**EN**	**VU**	**EN**
	Venezuela		EN	VU		EN	VU		EN	VU	**EN**
R. ephippium	**Range**	**EN**	**CR**	**VU**	**EN**	**CR**	**VU**		**CR**	**VU**	**CR**
	Ecuador	EN	CR	VU	EN	CR	VU		CR	VU	**CR**
R. escobarina	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Colombia		CR	VU			VU			VU	**VU**
R. falkenbergii	**Range**		**EN**	**VU**			**VU**			**VU**	**VU**
	Colombia		EN	VU			VU			VU	**VU**
R. flosculata	**Range**	**VU**	**EN**	**VU**	**VU**	**EN**	**VU**	**VU**	**EN**	**VU**	**EN**
	Colombia	EN	CR	VU	EN	CR	VU	EN	CR	VU	**CR**
	Ecuador	VU	EN	VU	VU	EN	VU		EN	VU	**EN**
R. guttulata	**Range**	**EN**	**EN**		**EN**			**EN**			**EN**
	Venezuela	CR			CR			EX	EX		**EX**
	Colombia	EN	EN		EN	EN		EN	EN		**EN**
	Ecuador	VU	EN		VU	EN			EN		**EN**
	Peru		CR	VU			VU			VU	**VU**
R. iris	**Range**	VU	EN	VU	VU	EN	VU	VU	EN	VU	**EN**
	Ecuador	VU	EN	VU	VU	EN	VU	VU	EN	VU	**EN**
R. jesupiana	**Range**	**CR**	**CR**	**VU**	**CR**	**CR**	**VU**		**CR**	**VU**	**CR**
	Venezuela	CR	CR	VU	CR	CR	VU		CR	VU	**CR**
R. lansbergii	**Range**		**EN**			**EN**			**EN**		**EN**
	Venezuela	VU	CR	VU	VU	CR	VU		CR	VU	**CR**

For Peer Review Only

	Ecuador	EN	CR	VU	EN	CR	VU		CR	VU	**CR**
	Peru	EN	CR	VU	EN		VU	EN		VU	**EN**
R. limbata	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Colombia		CR	VU			VU			VU	**VU**
R. mendozae	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Ecuador		CR	VU			VU			VU	**VU**
R. metae	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Colombia		CR	VU			VU			VU	**VU**
R. mohrii	**Range**	**EN**	**EN**	**VU**	**EN**	**EN**	**VU**	**EN**	**EN**	**VU**	**EN**
	Peru	EN	EN	VU	EN	EN	VU	EN	EN	VU	**EN**
R. muscifera	**Range**	**VU**	**EN**		**VU**			**VU**			**VU**
	Central America	VU	EN		VU			VU			**VU**
	Colombia	CR	CR	VU	CR	CR	VU		CR	VU	**CR**
	Ecuador	EN	CR	VU	EN		VU			VU	**VU**
R. nittioryncha	**Range**	**CR**	**CR**	**VU**	**CR**	**CR**	**VU**	**CR**	**CR**	**VU**	**CR**
	Colombia	CR	CR	VU	CR	CR	VU	CR	CR	VU	**CR**
R. pandurata	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Colombia		CR	VU			VU			VU	**VU**
R. pelyx	**Range**	**EN**	**EN**	**VU**	**EN**	**EN**	**VU**	**EN**	**EN**	**VU**	**EN**
	Venezuela	EN	CR	VU	EN	CR	VU		CR	VU	**CR**
	Colombia	EN	CR	VU	EN	CR	VU	VU	CR	VU	**CR**
R. purpurea	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Colombia		CR	VU			VU			VU	**VU**
R. radulifera	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Venezuela		CR	VU			VU			VU	**VU**
R. renzii	**Range**	**CR**	**CR**	**VU**	**CR**	**CR**	**VU**		**CR**	**VU**	**CR**
	Venezuela	CR	CR	VU	CR	CR	VU		CR	VU	**CR**
R. roseola	**Range**	**CR/EX**	**CR/EX**		**CR/EX**	**CR/EX**		**EX**	**EX**		**EX**
	Venezuela	CR/EX	CR/EX		CR/EX	CR/EX		EX	EX		**EX**
R. sanguinea	**Range**	**VU**	**EN**		**VU**	**EN**		**VU**	**EN**		**EN**
	Venezuela		EN	VU			VU			VU	**VU**
	Colombia	VU	EN	VU	VU	EN	VU		EN	VU	**EN**
R. schizosepala	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Ecuador		CR	VU			VU			VU	**VU**
R. seketii	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Colombia		CR	VU			VU			VU	**VU**

For Peer Review Only

R. tabeae	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Colombia		CR	VU			VU			VU	**VU**
R. teaguei	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Colombia		CR	VU			VU			VU	**VU**
R. trichoglossa	**Range**	**VU**	**EN**		**VU**			**VU**			**VU**
	Central America	EN	EN		EN			EN			**EN**
	Venezuela		CR	VU			VU			VU	**VU**
	Colombia		EN		LC	LC	LC	LC	LC	LC	**LC**
	Ecuador		EN		LC	LC	LC	LC	LC	LC	**LC**
R. tsubotae	**Range**		**CR**	**VU**			**VU**			**VU**	**VU**
	Colombia		CR	VU			VU			VU	**VU**
R. vasquezii	**Range**		**EN**	**VU**			**VU**			**VU**	**VU**
	Bolivia		EN	VU			VU			VU	**VU**
R. wagnerii	**Range**		**EN**	**VU**			**VU**			**VU**	**VU**
	Venezuela		EN	VU			VU			VU	**VU**
R. piperitosa*	*Peru*	DD	DD	DD	DD	DD	DD	DD	DD	DD	**DD**
R. portillae*	*Ecuador*		CR	VU			VU			VU	**VU**
R. howeii*	*Ecuador*	DD	DD	DD	DD	DD	DD	DD	DD	DD	**DD**
R. persiciana*	*Ecuador*		CR				VU			VU	**VU**
R. fritillina*	*Colombia*	DD	DD	DD	DD	DD	DD	DD	DD	DD	**DD**

[1] Red List values for each of the three criteria (A, B and D) used in the assessment. Sub-categories are not included for clarity, but numerical values employed are presented in Table 1.

[2] The Red List values for each of the criteria after amending for Criterion B. This could not be assigned if the additional sub-criteria (a) and (b) were not met as well (Table 1 and Notes).

[3] Red List values after the level of risk had been reduced for species with all or some occurrences in safe habitats such as National Parks or nature reserves.

The final Red List value is presented in the last column.

For Peer Review Only